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Relationship between muscular strength and balance in an elderly population

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Relationship between Muscular Strength and Balance in an Elderly Population

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Abstract

Purpose: To examine the association between grip strength, leg strength and balance test performance in elderly individuals. ***Methods:*** Four males and four females (average age = 72.8 ± 2.1 years, average height = 167.8 ± 9.4 cm, average weight = 74.8 ± 14.4 kg) participated in this study. Participants were administered the Berg Balance Test and assigned a score out of 56. They then performed a maximal grip strength test, and maximal isokinetic leg extension and flexion tests on their dominant leg to obtain peak torque. Correlations were calculated between all testing variables using Pearson correlation coefficients. ***Results:*** No significant correlations were found between the Berg Balance test scores and any of the strength measures (R=0.13-0.64). However, there was a trend towards significance between relative leg flexion strength and the Berg Balance test scores (R=0.64, p = 0.09). Significant correlations were found between grip strength and absolute leg flexion (R=0.80) and extension (R=0.92) strength. ***Conclusion:*** Grip strength was not found to be an accurate predictor of balance performance in elderly populations. This conclusion, however, is limited by the small number of subjects in this study and the lack of individuals at high risk of falling. However, grip strength may be an accurate predictor of leg flexion and extension strength in elderly populations.

Chapter I

Introduction

Falls in Older Adults. In 2016 unintentional injuries were the 3rd most common cause of death in the United States, an increase from 4th the previous year, accounting for 5.9% of deaths that year [1]. Of those unintentional injury deaths, 15.5% were fall related [1]. These data suggest that falls and injuries related to falls are becoming a greater risk in our society [1]. The overwhelming majority of these fall related deaths were in individuals 65 years or older, meaning that this subgroup of the population is at the greatest risk for fatal falls [1].

In 2000, an estimated 10,300 falls in US adults aged 65 and over were fatal, and another 2.6 million falls were nonfatal but required medical attention [2]. Amongst the fatal falls, 45.6% of them resulted in traumatic brain injuries [2]. Amongst the nonfatal falls, 1.3 million (50%) individuals sustained fractures or sprains [2]. Falls in US adults aged 65 and over, whether fatal or not fatal, can cause serious injury and impairment.

Donald and Bulpitt examined future prognoses of elderly patients over 75 [3]. They studied their instances of falls, mortality, and/or admission to care based on the number of falls within the previous three months [3]. 4.2% of participants reported falling more than once in the last three months, and the incidence of falls increased with age [3]. After the first year, those who had initially reported falling more than once in the previous three months had a mortality rate 2.6 times that of non-fallers; after three years, those who had initially reported falling more than once in the previous three months at the initial interview had a mortality rate 1.9 times that of non-fallers [3]. Furthermore, those who were a recurrent faller at the initial interview were 7 times more likely to be a recurrent faller at the subsequent interview, versus those who were non-fallers at the initial interview [3].

Thus, the risk of a fall being fatal in the elderly population is significant, and the more falls an individual has the more likely they are to fall again in the future. Therefore, the chances of one of their falls becoming fatal statistically increases with each fall that occurs.

Relationship Between Balance and Falls. Vermeulen et al. conducted a study on the influence of balance on instances of falls and disability in elderly individuals over 65 years [4]. Balance scores were assessed on a scale of 0-16, with 16 being perfect balance, and falls and disability were assessed by a questionnaire [4]. The balance score of participants who had reported falling in the past 6 months (8.9) was significantly lower than those who had not reported any falls (11.2) [4].

Bogle et al. evaluated elderly residents of independent living communities and the relationship between falls and scores on the Berg balance test initially and after 6 months [5]. Their results showed that the Berg Balance Test had high specificity, meaning the test correctly identified those who did not fall [5]. At the initial assessment, Berg scores correctly identified 96% of those who did not fall, while after the 6 month follow up scores correctly identified 92% of those who did not fall [5]. Both of the previously mentioned studies suggest that performance on a balance test can accurately distinguish between elderly individuals who are at risk for falling and those who are not.

Relationship Between Lower Limb Strength and Balance. A study on individuals at least 60 years of age compared their muscle strength, gait kinematics, and functional test performance in those who experienced falls compared to those who did not [6]. Knee flexor strength was found to be significantly lower in the fall group, while knee extensor and leg press 1RM/body weight strength was not different in the fall group versus the control group, [6].

Another study on women over 60 years old tested various lower limb strength tests (using maximal isometric voluntary contractions) to determine whether strength in specific muscular actions were associated with falls [7]. The measurements tested included knee flexion and extension, hip flexion, extension, abduction, and adduction, and ankle plantarflexion and dorsiflexion; for each of these peak torque and rate of force development were collected [7]. Of all of the tests, knee flexion rate of force development was the only one found to be significantly different between participants who had no falls and those who had one or more [7].

A study on 17 healthy older adults tested muscular strength measures in order to evaluate potential differences between groups of fallers and non-fallers [8]. Maximal forces were found to be lower in fallers than non-fallers for leg press, ankle plantarflexion, and knee extension [8]. Rate of moment development was slower in ankle plantarflexion and knee extension as well [8]. Of these variables leg press was the best predictor, accurately classifying 94% of cases of fallers versus non fallers [8].

Hasselgren, Olsson, & Nyberg recruited geriatric subjects to participate in tests of functional balance, mobility, and muscular strength [9]. Balance was tested using the Berg Balance Scale and muscular strength was tested using 1RM leg press/body weight as well as MRC grades for ankle plantarflexion and dorsiflexion [9]. Most of the 14 items of the Berg Balance Scale were significantly correlated to at least one of the muscular strength measures, with many being associated with all three [9]. Test items that required standing with a narrow base of support were found to be more highly correlated with 1RM leg press/body weight [9]. On the other hand, items that allowed the participant to choose foot position were more highly correlated with both measures of ankle strength [9].

Relationship Between Grip Strength and Balance. Leg strength protocols can be difficult to administer in certain subjects or scenarios, and for this reason an easier test with a similarly strong relationship would be beneficial for researchers and subjects, potentially a test such as grip strength. For example, those who are not familiar with weight lifting may not reach a successful 1RM, and without proper equipment it can be hard to accurately determine leg strength. A cross national study of men and women 75 years old analyzed postural control and its correlation to sensory-motor variables [10]. Balance was tested using the center of pressure on a force plate to determine the speed of anteroposterior movement, the speed of mediolateral movement, and the maximal amplitude of the elderly participants [10]. Of the isometric muscle strength tests performed, hand grip strength was noted as one of the two best predictors, ranking above knee extension [10]. This was especially true for men, where grip strength was one of the three best predictors of the postural control categories as compared to all tests completed including anthropometric characteristics, visual acuity, vibrotactile thresholds, and psychomotor speed [10].

Along with examining the relationship between leg strength and those who had fallen, the previously mentioned study by Pijnappels et al examined hand grip strength in these same individuals [8]. While not as strong a predictor as leg strength, grip strength was also found to be a significant measure in terms of identifying fallers from non-fallers as well as having a strong correlation with maximal leg press [8]. Though not directly used in control of balance, grip strength has been found to have a strong relationship with postural control, with increases in grip strength associated with greater control [8,10].

The purpose of the present study is to determine whether hand grip strength can be used as a predictor of performance on a balance test in elderly individuals in place of lower limb muscular strength tests. This will help health providers to more easily identify those at risk of falling due to bad balance. It is hypothesized that lower limb muscular strength will be a better predictor of balance performance than grip strength. However, it is also expected that grip strength will provide a moderately strong indication of balance performance.

Chapter II

Methods

Subjects. Twenty subjects will be recruited for this study, including males and females over 65 years of age. Subjects will be selected on a voluntary basis from the local retirement communities. Subjects will complete a balance test, grip strength test, and lower limb muscular strength test.

Balance Test. Balance scores of the subjects will be tested using the Berg Balance Test procedure. All 14 items of the Berg Balance Test will be performed in a standard order consistent across all subjects with verbal instructions given at the beginning of each item. This test will require a chair with arms, a meter stick, a pen, a step, and a Berg balance test score sheet to report results. Total scores will be reported out of 56, with a score range of 0 to 4 points per item, based upon the quality of performance or time to completion.

Grip Strength Test. Grip strength will be measured with a Takei Grip-D digital grip dynamometer. Subjects will be given instructions on proper posture and arm placement for the most accurate and consistent test results as described in the National Health and Nutrition Examination Survey [11]. Two trials will be performed on each hand alternating after each trial. The highest value on each side will be summed together to get a total grip strength score.

Lower Limb Muscular Strength Test. Lower limb muscular strength will be evaluated using leg extension and leg flexion tests on a Biodex dynamometer. Contractions will be performed at an angular velocity of 80 degrees per second with extension and flexion happening consecutively for five trials each. The peak torques of both extension and flexion will be used as the measures of dynamic lower-body strength.

Data Analysis. Data collected on each of these measures will be analyzed statistically to determine the correlations between grip strength and balance, and between leg flexion and extension and balance. Correlation coefficients will then be compared qualitatively to determine which is stronger. Independent t-tests will be also used to compare strength measures in those who scored in the high risk (< 45) or low risk (< 45) categories from the Berg balance test, as previous research has found these to be the most reliable cut of values [12]. A priori statistical significance will be set at $p < 0.05$.

Chapter III

Manuscript

Introduction

In 2016, unintentional injuries were the third most common cause of death in the United States, and 15.5% of these were fall related [1]. The overwhelming majority of these fall-related deaths were in individuals 65 years or older [1]. In 2000, an estimated 10,300 fatal falls occurred in US adults 65 years and over, and another 2.6 million falls were nonfatal but required medical attention [2]. Elderly individuals who reported recently falling multiple times had a one-year mortality rate 2.6 times greater than those who had reported no falls [3]. Both retrospective and prospective studies on balance as a predictor of falls have found significant relationships between higher balance scores and lower instances of falls [4,5].

Previous studies have found knee flexor measures of maximal strength and rate of force development to be significantly lower in subjects who experienced one or more falls [6,7]. Another study found maximal leg press was best measure for classifying cases of fallers versus non fallers [8]. Of the 14 items on the Berg Balance Test, most of them have been found to be associated with at least one if not multiple lower limb strength measures, including 1RM leg press, ankle plantarflexion and ankle dorsiflexion [9].

While not as strong a predictor as lower limb strength, grip strength has also been found to identify fallers from non-fallers and is easier to administer in elderly individuals [8,10]. However, whether grip strength and balance scores are as strongly associated as leg strength and balance scores is not known. Maximal leg strength protocols can be difficult to administer in elderly subjects due to safety concerns and access to equipment. For this reason, an easier test, such as grip strength, with a similarly strong relationship would help healthcare providers to more easily identify those at risk of falling due to bad balance. The purpose of the present study was to determine the association between grip strength, lower limb strength, and performance on a balance test in elderly individuals.

Methodology

Subjects. There were 8 subjects (4 males and 4 females) over 65 years old who participated in this study (average height = 167.8 ± 9.4 cm, average weight = 74.8 ± 14.4 kg). Age was not obtained from two subjects; the average age of the other six subjects was 72.8 ± 2.1 years. Subjects were selected on a voluntary basis from the local retirement communities. They were asked to complete a balance test, a grip strength test, and lower limb muscular strength tests via an isokinetic dynamometer. Prior to participation, all subjects filled out an Informed Consent form and a Health History Questionnaire.

Balance Test. Balance of the subjects was tested using the Berg Balance Test procedure[12]. All 14 items of the Berg Balance Test were performed in a standard order consistent across all subjects with verbal instructions given at the beginning of each item. Total scores were reported out of 56. This number represents a summation of scores for each item with a score range of 0 to 4 points per item, based upon the quality of performance or time to completion.

Grip Strength Test. Grip strength was measured with a Takei Grip-D digital grip dynamometer. Subjects were given instructions on proper posture and arm placement for the most accurate and consistent test results as described in the National Health and Nutrition Examination Survey [11]. Specifically, subjects stood upright with the arm kept at the side and the angle of the elbow between 0 and 90 degrees[11]. Two trials were performed on each hand alternating after each trial with 60 seconds rest. The highest value of each side was summed together to get a total grip strength score. Relative grip strength was calculated by dividing total grip strength by body weight in kilograms.

Lower Limb Muscular Strength Test. Lower limb muscular strength was evaluated using seated leg extension and leg flexion tests on a Biodex dynamometer. Contractions were performed at an angular velocity of 80 degrees per second with extension and flexion happening consecutively for five trials each using the dominant leg. The peak torques for both extension and flexion were used as the measures of dynamic lower-body strength. Both measures were reported as absolute strength and relative strength defined as peak torque divided by bodyweight in kg.

Data Analysis. Associations amongst grip strength, leg extension, leg flexion and balance were determined using Pearson correlation coefficients. A priori statistical significance was set at $p < 0.05$.

Results

There were no significant correlations between the Berg Balance Test and any of the strength measures as seen in Table 1. There was a trend found between relative leg flexion torque and the Berg Balance Test as seen in Figure 1 with a correlation coefficient of $R = 0.64$ ($p = 0.09$). However, significant correlations were found between grip strength and absolute leg extension and leg flexion torque ($R = 0.92$ and 0.80 respectively). In addition, significant correlations were found between relative grip strength and leg extension and relative leg extension peak torque ($R = 0.85$ and $R = 0.88$ respectively)

Discussion

In this study none of the strength measures were found to correlate with Berg Balance Test scores. This is does not support previous research in which multiple strength measures have been correlated with balance performance [6–10]. Specifically, Cebolla et al. found maximal knee flexor strength was different in those who had experienced falls as compared to those who had not, although only a trend was observed between relative knee flexor strength and balance scores[6]. Similar to the present findings, knee extensor strength was not correlated with balance or falls [6]. Era et al. observed that grip strength was an accurate predictor of balance in older adults, while the current study found no correlation between the two [10].

One obvious reason for the lack of correlations with Berg Balance Test scores could be the limited number of subjects and low variability within the sample. There were only eight subjects in this study with a Berg Balance Test score range of 51-56. The previously established threshold to designate a subject as being at a high risk of falls is a score of 45 on the Berg Balance Test [12]. A study with more subjects and a greater range of balance capabilities would better determine if there is a stronger statistical correlation between these strength measures and balance. The fact that the balance scores were confined to a relatively high and narrow range could be due to the requirement for the subjects to visit James Madison University campus for testing. The subjects most often had to be able to independently transport themselves, meaning they were likely independent on a daily basis and thus may not have had diminished balance.

It is possible that the trend observed between relative knee flexor strength and balance is due to the pattern of muscle activation during fall recovery. Previous research has found that in terms of timing, the biceps femoris, a knee flexor muscle, is one of the first muscles of the lower limb to be recruited during a recovery step in both legs [13,14]. In support of this, it has been observed that biceps femoris activity peaks sooner in non-fallers than in fallers [14]. Furthermore, bilateral knee flexor strength has been found to be positively correlated with the Y balance test, another test of dynamic balance [15]. Confidence in balancing ability, as measured by the

Activities-Specific Balance Confidence test, has a moderate to strong correlation with Berg Balance test scores [16,17]. Thus, if the knee flexors are sufficiently strong to initiate early recovery from a potential fall after loss of balance, then less falls may occur and confidence may increase.

In addition to the trend found between relative knee flexion and the Berg Balance test, statistically significant correlations were found between grip strength and all measures of lower limb strength. Maximal knee extension strength has been otherwise found to have a correlation with grip strength, typically with a correlation coefficient just above 0.70, which is lower than the 0.92 coefficient found in this study between absolute isokinetic knee extension peak torque and grip strength [8,18]. Maximal leg press has previously shown a correlation as well, albeit to a moderate degree [8,18]. Literature which addresses the association between knee flexor strength and grip strength is minimal.

The practical purpose of this study was to determine if grip strength is as associated with balance as lower-body strength and thus could be used as a single strength measure in health-related fitness testing. While these data do not show an association between grip strength and balance, our findings as well as previous literature suggest that maximal knee extension strength is highly correlated with grip strength [8,18]. Current research supports knee extensor strength as a test of functional capability in elderly populations to predict many factors, including sit-to-stand performance, pulmonary function, and many other physical, nutritional, and psychological characteristics [19–21]. Thus, grip strength may be able to predict function for these characteristics as well, and prove a relatively easy test as compared to maximal leg extension. Future research would be necessary to prove that this correlation between grip strength and knee extensor strength translates to functional tests in older populations.

Manuscript References

1. Xu J, Murphy SL, Kochanek KD, Bastian B, Arias E. Deaths: Final data for 2016. *Natl Vital Staitistics Rep*. 2018;67(5).
2. Stevens JA, Corso PS, Finkelstein EA, Miller TR. The costs of fatal and non-fatal falls among older adults. *Inj Prev*. 2006. doi:10.1136/ip.2005.011015
3. Donald IP, Bulpitt CJ. The prognosis of falls in elderly people living at home. *Age Ageing*. 1999. doi:10.1093/ageing/28.2.121
4. Vermeulen J, Neyens JCL, Spreeuwenberg MD, et al. The relationship between balance measured with a modified bathroom scale and falls and disability in older Adults:a 6-month follow-up study. *J Med Internet Res*. 2015. doi:10.2196/jmir.3802
5. Bogle Thorbahn LD, Newton RA. Use of the Berg Balance Test to Predict Falls in Elderly Persons. *Phys Ther*. 1996. doi:10.1093/ptj/76.6.576
6. Cebolla EC, Rodacki ALF, Bento PCB. Balance, gait, functionality and strength: Comparison between elderly fallers and non-fallers. *Brazilian J Phys Ther*. 2015. doi:10.1590/bjpt-rbf.2014.0085
7. Bento PCB, Pereira G, Ugrinowitsch C, Rodacki ALF. Peak torque and rate of torque development in elderly with and without fall history. *Clin Biomech*. 2010. doi:10.1016/j.clinbiomech.2010.02.002
8. Pijnappels M, van der Burg JCE, Reeves ND, van Dieën JH. Identification of elderly fallers by muscle strength measures. *Eur J Appl Physiol*. 2008. doi:10.1007/s00421-007-0613-6
9. Hasselgren L, Olsson LL, Nyberg L. Is leg muscle strength correlated with functional balance and mobility among inpatients in geriatric rehabilitation? *Arch Gerontol Geriatr*.

2011. doi:10.1016/j.archger.2010.11.016

10. Era P, Schroll M, Ytting H, Gause-Nilsson I, Heikkinen E, Steen B. Postural balance and its sensory-motor correlates in 75-year-old men and women: A cross-national comparative study. *Journals Gerontol - Ser A Biol Sci Med Sci*. 1996. doi:10.1093/gerona/51A.2.M53

11. Center for Disease Control and Prevention. Muscle Strength Procedures Manual. *Natl Heal Nutr Exam Surv*. 2011.

12. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: Validation of an instrument. In: *Canadian Journal of Public Health*. ; 1992. doi:10.1016/j.archger.2009.10.008

13. Thelen DG, Muriuki M, James J, Schultz AB, Ashton-Miller JA, Alexander NB. Muscle activities used by young and old adults when stepping to regain balance during a forward fall. *J Electromyogr Kinesiol*. 2000. doi:10.1016/S1050-6411(99)00028-0

14. Ochi A, Yokoyama S, Abe T, Yamada K, Tateuchi H, Ichihashi N. Differences in muscle activation patterns during step recovery in elderly women with and without a history of falls. *Aging Clin Exp Res*. 2014. doi:10.1007/s40520-013-0152-4

15. Lee DK, Kang MH, Lee TS, Oh JS. Relationships among the Y balance test, Berg Balance Scale, and lower limb strength in middle-aged and older females. *Brazilian J Phys Ther*. 2015. doi:10.1590/bjpt-rbf.2014.0096

16. Lajoie Y, Gallagher SP. Predicting falls within the elderly community: Comparison of postural sway, reaction time, the Berg balance scale and the Activities-specific Balance Confidence (ABC) scale for comparing fallers and non-fallers. *Arch Gerontol Geriatr*. 2004. doi:10.1016/S0167-4943(03)00082-7

17. Holbein-Jenny MA, Billek-Sawhney B, Beckman E, Smith T. Balance in personal care

home residents: a comparison of the Berg Balance Scale, the Multi-Directional Reach Test, and the Activities-Specific Balance Confidence Scale. *J Geriatr Phys Ther*. 2005. doi:10.1519/00139143-200508000-00003

18. Trosclair D, Bellar D, Judge LW, Smith J, Mazerat N, Brignac A. Hand-Grip Strength as a Predictor of Muscular Strength and Endurance. *J Strength Cond Res*. 2011. doi:10.1097/01.jsc.0000395736.42557.bc
19. Crockett K, Ardell K, Hermanson M, et al. The relationship of knee-extensor strength and rate of torque development to sit-to-stand performance in older adults. *Physiother Canada*. 2013. doi:10.3138/ptc.2012-04
20. Lee J, Han D. Association between knee extensor strength and pulmonary function in the female elderly. *J Phys Ther Sci*. 2018;30(2):234-237. doi:10.1589/jpts.30.234
21. Yeung SSY, Reijnierse EM, Trappenburg MC, Blauw GJ, Meskers CGM, Maier AB. Knee extension strength measurements should be considered as part of the comprehensive geriatric assessment. *BMC Geriatr*. 2018. doi:10.1186/s12877-018-0815-2

Table 1. Correlations between each measured variable of balance, grip strength, and lower limb isokinetic muscular strength. *Significant correlation (P < 0.05)

	Berg Balance Test	Grip Strength (Kg)	Relative Grip Strength (Kg/Kg)	Absolute Leg Extension Torque (Nm)	Relative Leg Extension Torque (Nm/Kg)	Absolute Leg Flexion Torque (Nm)	Relative Leg Flexion Torque (Nm/Kg)
Berg Balance Test	1	0.13	0.38	0.13	0.32	0.42	0.64
Grip Strength (Kg)	0.13	1	0.83	0.92*	0.63	0.80*	0.46
Relative Grip Strength (Kg/Kg)	0.38	0.83	-	0.85*	0.88*	0.66	0.62
Absolute Leg Extension Torque (Nm)	0.13	0.92*	0.85*	1	0.85*	0.73*	0.51
Relative Leg Extension Torque (Nm/Kg)	0.32	0.63	0.88*	0.85*	1	0.51	0.58
Absolute Leg Flexion Torque (Nm)	0.42	0.80*	0.66	0.73*	0.51	1	0.84*
Relative Leg Flexion Torque (Nm/Kg)	0.64	0.46	0.62	0.51	0.58	0.84*	1

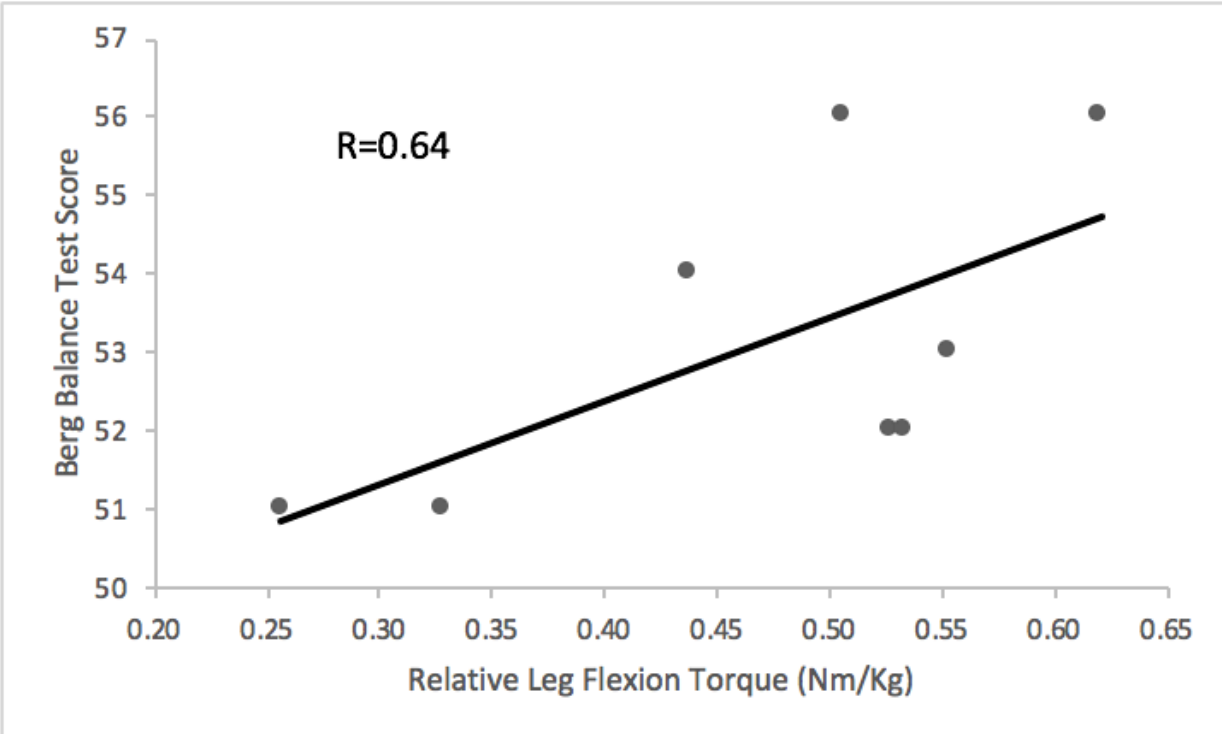

Figure 1. The effect of relative leg flexion torque on Berg Balance Test Score.

Appendix A

Informed Consent Form

Consent to Participate in Research

Identification of Investigators & Purpose of Study

You are being asked to participate in a research study conducted by Mikayla Basil and Dr. Christopher Womack from James Madison University. The purpose of this study is to determine the ability of maximal grip strength and maximal leg strength to predict performance on the Berg Balance Test. This study will contribute to the researcher's completion of her senior thesis.

Research Procedures

Should you decide to participate in this research study, you will be asked to sign this consent form once all your questions have been answered to your satisfaction. This study consists of a one visit to the Human Performance Lab in Godwin Hall. You will be asked to complete a Berg Balance test, a maximal leg strength test on a Biodex dynamometer, and a maximal grip strength test on a Grip Dynamometer.

Time Required

Participation in this study will require 30 minutes of your time during one visit.

Risks

The investigator perceives the following are possible risks arising from your involvement with this study: Slight discomfort during maximal exertion of muscles, and potential soreness for up to 72 hours after the test. There may also be psychological stress due to fear of falling during the balance test, but at least one of the investigators will be supervising the test to be prepared in the case of loss of balance. In the unlikely case of a cardiac event, at least one investigator present will be CPR certified.

Benefits

Potential societal benefits from participation in this study include more efficient use of time during rehabilitation appointments while completing the same tasks as well as increasing the use of grip strength as a functional test. There are no direct benefits to participants

Confidentiality

The results of this research may be presented at research conferences or published in research journals. The results of this project will be coded in such a way that the respondent's identity will not be attached to the final form of this study. The researcher retains the right to use and publish non-identifiable data. While individual responses are confidential, aggregate data will be presented representing averages or generalizations about the responses as a whole. All data will be stored in a secure location accessible only to the researchers. Upon completion of the study, all information that matches up individual respondents with their answers will be destroyed.

Participation & Withdrawal

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind.

Questions about the Study

If you have questions or concerns during the time of your participation in this study, or after its completion or you would like to receive a copy of the final aggregate results of this study, please contact:

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Questions about Your Rights as a Research Subject

Dr. Taimi Castle
Chair, Institutional Review Board
James Madison University
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Giving of Consent

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

____
Name of Participant (Printed)

______________________________________ ______________
Name of Participant (Signed) Date

______________________________________ ______________
Name of Researcher (Signed) Date

Appendix B

Health History Questionnaire

James Madison University
Department of Kinesiology
Health Status Questionnaire

Instructions: Complete each question accurately. All information provided is confidential.
Part I: General Information

1. Subject #

2. Local Phone Email: ____________________________________

3. Gender (circle one) Male Female

4. Date of Birth (Month/ Day/ Year)

Part II: Medical History

5. Circle any that died of heart attack before age 50: Father Mother Brother Sister Grandparent

6. Date of last medical exam: _____________ Last physical fitness test: _______________

7. Circle operations you have had: Back Heart Kidney Eyes Joint Neck Ears Hernia

Lung Other ________________

8. Please circle any of the following for which you have been diagnosed or treated by a physician or health professional:

Alcoholism	Diabetes	Kidney Problems
Anemia (sickle cell)	Emphysema	Mental Illness
Anemia (other)	Epilepsy	Muscular Injury
Asthma	Eye Problems	Neck Strain
Back Strain	Gout	Obesity
Bleeding trait	Hearing Loss	Orthopedic Injuries
Bronchitis, chronic	Heart Problem	Phlebitis
Cancer	High Blood Pressure	Rheumatoid arthritis
Cirrhosis, liver	Hypoglycemia	Stroke
Concussion	Hyperglycemia	Thyroid problem
Congenital defect	Infectious Mononucleosis	Ulcer

Other _____________________

9. Circle all medications taken in the last six months:

Blood thinner	Epilepsy or anti-seizure medication	Nitroglycerin
Diabetic pill	Heart-rhythm medication	Other __________________

Digitalis	High-blood pressure medication
Diuretic	Insulin
Anabolic steroids/testosterone	Acetaminophen (Tylenol)
Anti-ulcer/heartburn	Oral contraceptives
Acne medication (Accutane)	Arthritis treatment
Anti-anxiety/insomnia	Anti-depressants

10. Any of these health symptoms that occur frequently is the basis for medical attention. Circle the
number indicating how often you have each of the following:

5 = Very often 4 = Fairly often 3 = Sometimes 2 = Infrequently 1= Practically never

a. cough up blood	f. chest pain
1 2 3 4 5	1 2 3 4 5
b. abdominal pain	g. swollen joints
1 2 3 4 5	1 2 3 4 5
c. low back pain	h. feel faint
1 2 3 4 5	1 2 3 4 5
d. leg pain	i. dizziness
1 2 3 4 5	1 2 3 4 5
e. arm or shoulder pain	j. breathless on slight exertion
1 2 3 4 5	1 2 3 4 5

Part III: Health Related Behavior

11. Do you smoke? Yes No

12. If you are a smoker, indicate the number of smoked per day:

Cigarettes:

40 or more 20-39 10-19 1-9

Cigars or pipes only:

5 or more or any inhaled less than 5, none inhaled

13. Do you exercise regularly? Yes No

14. How many times in a week do you spend at least 30 minutes in moderate to strenuous/vigorous

exercise?

1 2 3 4 5 6 7 days per week

15. Can you walk 4 miles briskly without fatigue? Yes No

16. Can you jog 3 miles continuously at a moderate pace without discomfort? Yes No

17. Weight now: __________ lb. One year ago: __________ lb Age 21: __________ lb

Appendix C

Berg Balance Scale

Description:

14-item scale designed to measure balance of the older adult in a clinical setting.

Equipment needed: Yardstick, 2 standard chairs (one with arm rests, one without), Footstool or step, Stopwatch or wristwatch, 15 ft walkway

Scoring: A five-point ordinal scale, ranging from 0-4. "0" indicates the lowest level of function and "4" the
highest level of function. Score the LOWEST performance. Total Score = 56

Interpretation: **41-56 = independent**
21-40 = walking with assistance
0 –20 = wheelchair bound

Berg K, Wood-Dauphinee S, Williams JI, Maki, B (1992). Measuring balance in the elderly: validation of an instrument. Can. J. Pub. Health July/August supplement 2:S7-11

Cut Off Scores:

- Score of < 45 indicates individuals may be at greater risk of falling (Berg, 1992)

  Berg K, Wood-Dauphinee S, Williams JI, Maki, B. (1992). Measuring balance in the elderly: validation of an instrument. Can. J. Pub. Health July/August supplement 2:S7-11

- History of falls and BBS < 51, or no history of falls and BBS < 42 is predictive of falls (91% sensitivity, 82% specificity) (Shumway-Cook, 1997)
- Score of < 40 on BBS associated with almost 100% fall risk (Shumway-Cook, 1997)

  (n = 44, mean age = 74.6 (5.4) years for non-fallers, 77.6 (7.8) for fallers)

  Shumway-Cook, A., Baldwin, M., et al. (1997). Predicting the probability for falls in community-dwelling older adults. Physical Therapy 77(8): 812-819
  Retrieved 10-5-2014 from Rehab Measures Database.
  http://www.rehabmeasures.org/Lists/RehabMeasures/PrintView.aspx?ID=888

Comments: Potential ceiling effect with higher level patients. Scale does not include gait items

Minimal Detectable Change:

"A change of **4 points** is needed to be 95% confident that true change has occurred if a patient scores within 45-56 initially, **5 points** if they score within 35-44, **7 points** if they score within 25-34 and, finally, **5 points** if their initial score is within 0-24 on the Berg Balance Scale."

Donoghue D; Physiotherapy Research and Older People (PROP) group, Stokes EK. (2009). How much change is true change? The minimum detectable change of the Berg Balance Scale in elderly people. *J Rehabil Med*. 41(5):343-6.

Norms:

Table 4. Berg Balance Scale Scores: Means, Standard Deviations, and Confidence Intervals by Age, Gender, and Use of Assistive Device

Age (y)	Group	N	Mean	SD	CI
60-69	Male	1	51.0	—	35.3 – 66.7
	Female	5	54.6	0.5	47.6 – 61.6
	Overall	6	54.0	1.5	52.4 – 55.6
70-79	Male	9	53.9	1.5	48.7 – 59.1
	Female	10	51.6	2.6	46.6 – 56.6
	Overall	19	52.7	2.4	51.5 – 53.8
80-89	Male	10	41.8	12.2	36.8 – 46.8
	Female	24	42.1	8.0	38.9 – 45.3
	No Device	24	46.3	4.2	44.1 – 48.5
	Device	10	31.7	10.0	28.3 – 35.1
	Overall	34	42.0	9.2	38.8 – 45.3
90-101	Male	2	40.0	1.4	28.9 – 51.1
	Female	15	36.9	9.7	32.8 – 40.9
	No Device	7	45	4.2	40.9 – 49.1
	Device	10	31.8	7.6	28.4 – 35.2
	Overall	17	37.2	9.1	32.5 – 41.9

Lusardi, M.M. (2004). Functional Performance in **Community Living Older Adults**. *Journal of Geriatric Physical Therapy*, 26(3), 14-22.

Berg Balance Scale

Name: ___________________________________ Date: ____________________

Location: _________________________________ Rater: ____________________

ITEM DESCRIPTION SCORE (0-4)

1. Sitting to standing ________
2. Standing unsupported ________
3. Sitting unsupported ________
4. Standing to sitting ________
5. Transfers ________
6. Standing with eyes closed ________
7. Standing with feet together ________
8. Reaching forward with outstretched arm ________
9. Retrieving object from floor ________
10. Turning to look behind ________
11. Turning 360 degrees ________
12. Placing alternate foot on stool ________
13. Standing with one foot in front ________
14. Standing on one foot ________

Total ________

GENERAL INSTRUCTIONS
Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- the time or distance requirements are not met
- the subject's performance warrants supervision
- the subject touches an external support or receives assistance from the examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be a reasonable height. Either a step or a stool of average step height may be used for item # 12.

Berg Balance Scale

1. SITTING TO STANDING

INSTRUCTIONS: Please stand up. Try not to use your hand for support.

( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

2. STANDING UNSUPPORTED

INSTRUCTIONS: Please stand for two minutes without holding on.

( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

3. SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL

INSTRUCTIONS: Please sit with arms folded for 2 minutes.

( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

4. STANDING TO SITTING

INSTRUCTIONS: Please sit down.

( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

5. TRANSFERS

INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.

( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

6. STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

7. STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

8. REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

9. PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is place in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm(1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

10. TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning

( ) 0 needs assist to keep from losing balance or falling

11. TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

12. PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touch the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

13. STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

14. STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold ≥ 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0 unable to try of needs assist to prevent fall

( ) TOTAL SCORE (Maximum = 56)

Appendix D

Data Collection Sheet

Subject #________________

Body weight (kg):________________

Height (in):________________

Balance

Berg Balance Test score:________________

Berg Balance Test category: High (>45)   Low (<45)

Maximal grip strength

Grip strength R1:________________ Grip strength R2:________________ □dominant

Grip strength L1:________________ Grip strength L2:________________ □dominant

Grip strength total (sum of highest measure for each hand):________________

Maximal lower limb strength

dominant leg: R □ L □

Peak leg extension torque:________________

Peak leg extension torque/Bodyweight:________________

Peak leg flexion torque:________________

Peak leg flexion torque/Bodyweight:________________

Q:H ratio:________________

Bibliography

1. Xu J, Murphy SL, Kochanek KD, Bastian B, Arias E. Deaths: Final data for 2016. *Natl Vital Staitistics Rep*. 2018;67(5).

2. Stevens JA, Corso PS, Finkelstein EA, Miller TR. The costs of fatal and non-fatal falls among older adults. *Inj Prev*. 2006. doi:10.1136/ip.2005.011015

3. Donald IP, Bulpitt CJ. The prognosis of falls in elderly people living at home. *Age Ageing*. 1999. doi:10.1093/ageing/28.2.121

4. Vermeulen J, Neyens JCL, Spreeuwenberg MD, et al. The relationship between balance measured with a modified bathroom scale and falls and disability in older Adults:a 6-month follow-up study. *J Med Internet Res*. 2015. doi:10.2196/jmir.3802

5. Bogle Thorbahn LD, Newton RA. Use of the Berg Balance Test to Predict Falls in Elderly Persons. *Phys Ther*. 1996. doi:10.1093/ptj/76.6.576

6. Cebolla EC, Rodacki ALF, Bento PCB. Balance, gait, functionality and strength: Comparison between elderly fallers and non-fallers. *Brazilian J Phys Ther*. 2015. doi:10.1590/bjpt-rbf.2014.0085

7. Bento PCB, Pereira G, Ugrinowitsch C, Rodacki ALF. Peak torque and rate of torque development in elderly with and without fall history. *Clin Biomech*. 2010. doi:10.1016/j.clinbiomech.2010.02.002

8. Pijnappels M, van der Burg JCE, Reeves ND, van Dieën JH. Identification of elderly fallers by muscle strength measures. *Eur J Appl Physiol*. 2008. doi:10.1007/s00421-007-0613-6

9. Hasselgren L, Olsson LL, Nyberg L. Is leg muscle strength correlated with functional balance and mobility among inpatients in geriatric rehabilitation? *Arch Gerontol Geriatr*.

2011. doi:10.1016/j.archger.2010.11.016

10. Era P, Schroll M, Ytting H, Gause-Nilsson I, Heikkinen E, Steen B. Postural balance and its sensory-motor correlates in 75-year-old men and women: A cross-national comparative study. *Journals Gerontol - Ser A Biol Sci Med Sci*. 1996. doi:10.1093/gerona/51A.2.M53

11. Center for Disease Control and Prevention. Muscle Strength Procedures Manual. *Natl Heal Nutr Exam Surv*. 2011.

12. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: Validation of an instrument. In: *Canadian Journal of Public Health*. ; 1992. doi:10.1016/j.archger.2009.10.008

13. Thelen DG, Muriuki M, James J, Schultz AB, Ashton-Miller JA, Alexander NB. Muscle activities used by young and old adults when stepping to regain balance during a forward fall. *J Electromyogr Kinesiol*. 2000. doi:10.1016/S1050-6411(99)00028-0

14. Ochi A, Yokoyama S, Abe T, Yamada K, Tateuchi H, Ichihashi N. Differences in muscle activation patterns during step recovery in elderly women with and without a history of falls. *Aging Clin Exp Res*. 2014. doi:10.1007/s40520-013-0152-4

15. Lee DK, Kang MH, Lee TS, Oh JS. Relationships among the Y balance test, Berg Balance Scale, and lower limb strength in middle-aged and older females. *Brazilian J Phys Ther*. 2015. doi:10.1590/bjpt-rbf.2014.0096

16. Lajoie Y, Gallagher SP. Predicting falls within the elderly community: Comparison of postural sway, reaction time, the Berg balance scale and the Activities-specific Balance Confidence (ABC) scale for comparing fallers and non-fallers. *Arch Gerontol Geriatr*. 2004. doi:10.1016/S0167-4943(03)00082-7

17. Holbein-Jenny MA, Billek-Sawhney B, Beckman E, Smith T. Balance in personal care

home residents: a comparison of the Berg Balance Scale, the Multi-Directional Reach Test, and the Activities-Specific Balance Confidence Scale. *J Geriatr Phys Ther*. 2005. doi:10.1519/00139143-200508000-00003

18. Trosclair D, Bellar D, Judge LW, Smith J, Mazerat N, Brignac A. Hand-Grip Strength as a Predictor of Muscular Strength and Endurance. *J Strength Cond Res*. 2011. doi:10.1097/01.jsc.0000395736.42557.bc

19. Crockett K, Ardell K, Hermanson M, et al. The relationship of knee-extensor strength and rate of torque development to sit-to-stand performance in older adults. *Physiother Canada*. 2013. doi:10.3138/ptc.2012-04

20. Lee J, Han D. Association between knee extensor strength and pulmonary function in the female elderly. *J Phys Ther Sci*. 2018;30(2):234-237. doi:10.1589/jpts.30.234

21. Yeung SSY, Reijnierse EM, Trappenburg MC, Blauw GJ, Meskers CGM, Maier AB. Knee extension strength measurements should be considered as part of the comprehensive geriatric assessment. *BMC Geriatr*. 2018. doi:10.1186/s12877-018-0815-2